CS 444/544 OS II
Lab Tutorial #2 (part 2)

Stack and Calling Convention

Acknowledgement: Slides drawn heavily from Yeongjin Jiang

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- Stack and calling convention
- Exercise 7-11

Exercise 7: Virtual Memory

- 0xf0000000 == KERNBASE

- Virtual address 0xf0000000 ~ 0xffffffff
  - Access physical address at (Virtual address – KERNBASE)
- E.g.,
  - 0xf0123456 -> 0x123456
  - 0xf0000001 -> 0x1

Exercise 8

- Read lib/printfmt.c, for vprintfmt()

- Look at cases ‘x’ and ‘u’ as an example of hexadecimal and decimal

- Implement the case ‘o’
  - Similar to ‘x’ and ‘u’
  - It’s easy…

Exercise 9 ~ 11: Stack Backtrace

- Must understand how stack works in x86..

> **Exercise 10.** To become familiar with the C calling conventions on the x86, find the address of the *test_backtrace*` function in `obj/kern/kernel.asm`, set a breakpoint there, and examine what happens each time it gets called after the kernel starts. How many 32-bit words does each recursive nesting level of `test_backtrace` push on the stack, and what are those words? NOTE. you'll have to manually translate all breakpoint and memory addresses to linear addresses.

Function call in x86

In kern/init.c

```
38          // Test the stack backtrace function (lab 1 only)
39          test_backtrace(5);
```

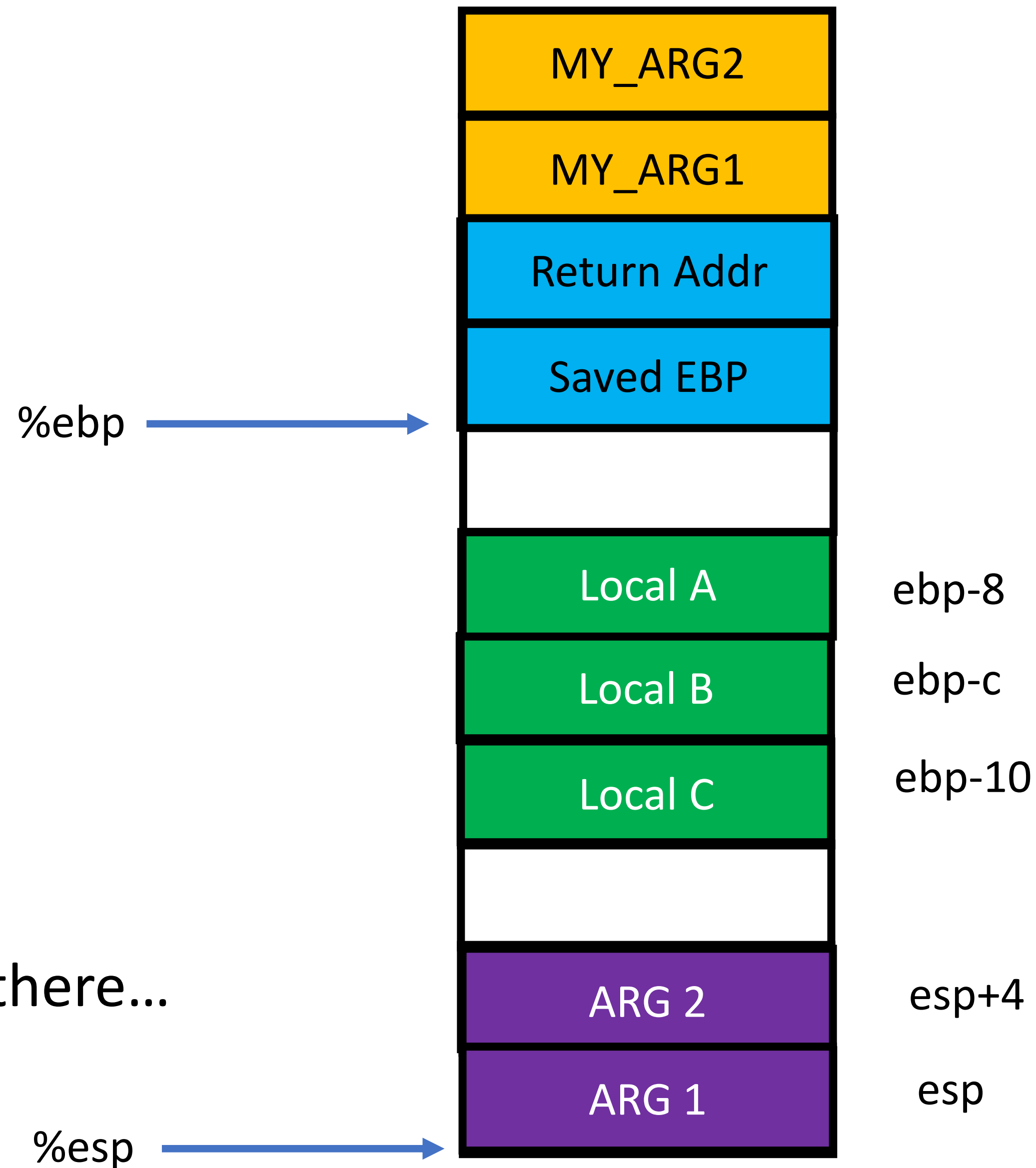
```
10 // Test the stack backtrace function (lab 1 only)
11 void
12 test_backtrace(int x)
13 {
14         cprintf("entering test_backtrace %d\n", x);
15         if (x > 0)
16                 test_backtrace(x-1);
17         else
18                 mon_backtrace(0, 0, 0);
19         cprintf("leaving test_backtrace %d\n", x);
20 }
```

test_backtrace(5) -> test_backtrace(4) -> test_backtrace(3) -> 2 -> 1 -> mon_backtrace(0,0,0)…

How this recursion can work in x86 computer?

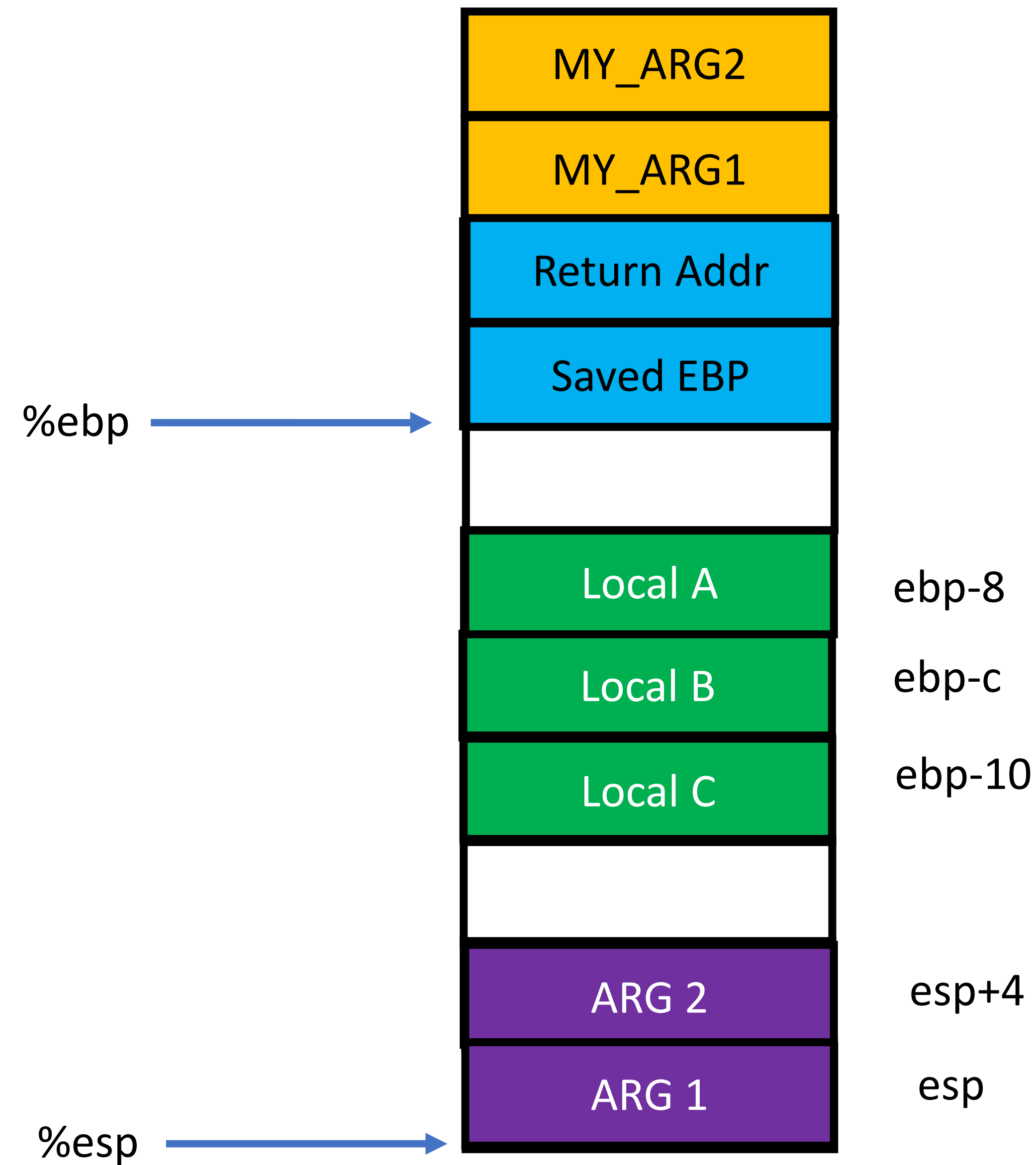
x86 Stack

- All local variables are stored in the stack.
- A function call creates a new stack
  - Start with `ebp`, ends with `esp`
- Grows downward!
  - Push(A), subtract 4 from `esp` and store A to there…
  - Pop, get the value at `esp` and add 4 to `esp`



Function call example

```
my_function(MY_ARG1, MY_ARG2) {
    int A;
    int B;
    int C;
    other_function(ARG1, ARG2)
}
```



How x86 manages stack?

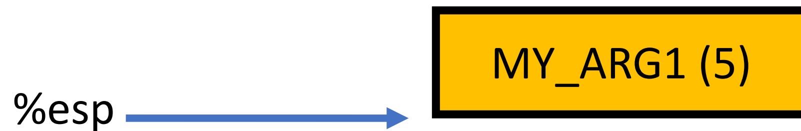
- Let’s debug calling test_backtrace
- Set the breakpoint at *i386_init

```
Breakpoint 1, i386_init () at kern/init.c:24
24          {
─── Registers ──────────────────────────────────────────────────────────────
   eax 0xf010002f     ecx 0x00000000     edx 0x0000009d     ebx 0x00010094    e
eflags [ PF SF ]       cs 0x00000008      ss 0x00000010      ds 0x00000010
─── Assembly ───────────────────────────────────────────────────────────────
0xf010009d i386_init+0 push   %ebp
0xf010009e i386_init+1 mov    %esp,%ebp
0xf01000a0 i386_init+3 sub    $0x18,%esp
0xf01000a3 i386_init+6 mov    $0xf0112940,%eax
─── Source ─────────────────────────────────────────────────────────────────
19      cprintf("leaving test_backtrace %d\n", x);
20 }
21
22 void
23 i386_init(void)
24 {
25      extern char edata[], end[];
26
27      // Before doing anything else, complete the ELF loading process.
28      // Clear the uninitialized global data (BSS) section of our program.
29      // This ensures that all static/global variables start out zero.
─── Stack ──────────────────────────────────────────────────────────────────
[0] from 0xf010009d in i386_init+0 at kern/init.c:24
(no arguments)
─── Memory ─────────────────────────────────────────────────────────────────
─── Expressions ────────────────────────────────────────────────────────────
───────────────────────────────────────────────────────────────────────────
>>> 
1:  gdb 0:make- 1:gdb*
```

```
+ symbol-file obj/kern/kernel
>>> b *i386_init
Breakpoint 1 at 0xf010009d: file kern/init.c, line 24.
>>> c
```

How x86 manages stack?

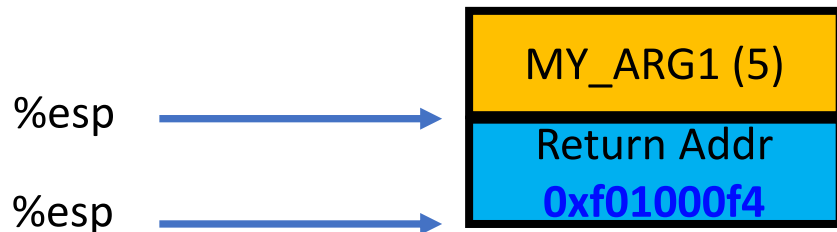
- Examine instructions…




```
gdb-peda$ x/25i $pc
=> 0xf01000a6 <i386_init>:      push   %ebp
   0xf01000a7 <i386_init+1>:    mov    %esp,%ebp
   0xf01000a9 <i386_init+3>:    push   %ebx
   0xf01000aa <i386_init+4>:    sub    $0x8,%esp
   0xf01000ad <i386_init+7>:
    call   0xf01001bc <__x86.get_pc_thunk.bx>
   0xf01000b2 <i386_init+12>:   add    $0x11256,%ebx
   0xf01000b8 <i386_init+18>:   mov    $0xf0113060,%edx
   0xf01000be <i386_init+24>:   mov    $0xf01136a0,%eax
   0xf01000c4 <i386_init+30>:   sub    %edx,%eax
   0xf01000c6 <i386_init+32>:   push   %eax
   0xf01000c7 <i386_init+33>:   push   $0x0
   0xf01000c9 <i386_init+35>:   push   %edx
   0xf01000ca <i386_init+36>:   call   0xf010179a <memset>
   0xf01000cf <i386_init+41>:   call   0xf0100611 <cons_init>
   0xf01000d4 <i386_init+46>:   add    $0x8,%esp
   0xf01000d7 <i386_init+49>:   push   $0x1aac
   0xf01000dc <i386_init+54>:   lea    -0xf6f1(%ebx),%eax
   0xf01000e2 <i386_init+60>:   push   %eax
   0xf01000e3 <i386_init+61>:   call   0xf0100b86 <cprintf>
   0xf01000e8 <i386_init+66>:   movl   $0x5,(%esp)
   0xf01000ef <i386_init+73>:   call   0xf0100040 <test_backtrace>
   0xf01000f4 <i386_init+78>:   add    $0x10,%esp
   0xf01000f7 <i386_init+81>:   sub    $0xc,%esp
   0xf01000fa <i386_init+84>:   push   $0x0
   0xf01000fc <i386_init+86>:   call   0xf01009ce <monitor>
```

How x86 manages stack?

- Call
  - Push addr of next instr.
    - To return to there after func().
  - Jump to target.

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    call   0xf01001bc <__x86.get_pc_thunk.bx>
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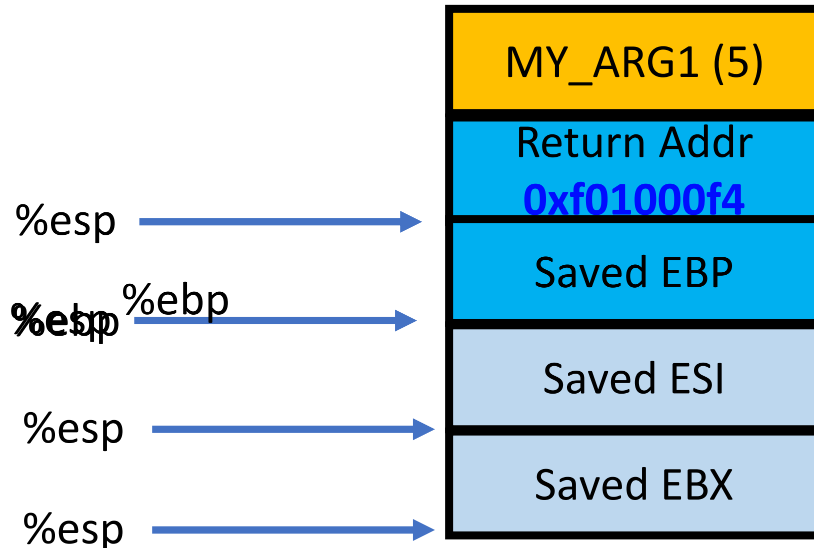
   0xf01000fc <i386_init+86>:   call   0xf01009ce <monitor>
```

How x86 manages stack?

- In test backtrace

```
gdb-peda$ disas test_backtrace
Dump of assembler code for function test_backtrace:
   0xf0100040 <+0>:     push   %ebp
   0xf0100041 <+1>:     mov    %esp,%ebp
   0xf0100043 <+3>:     push   %esi
   0xf0100044 <+4>:     push   %ebx
```

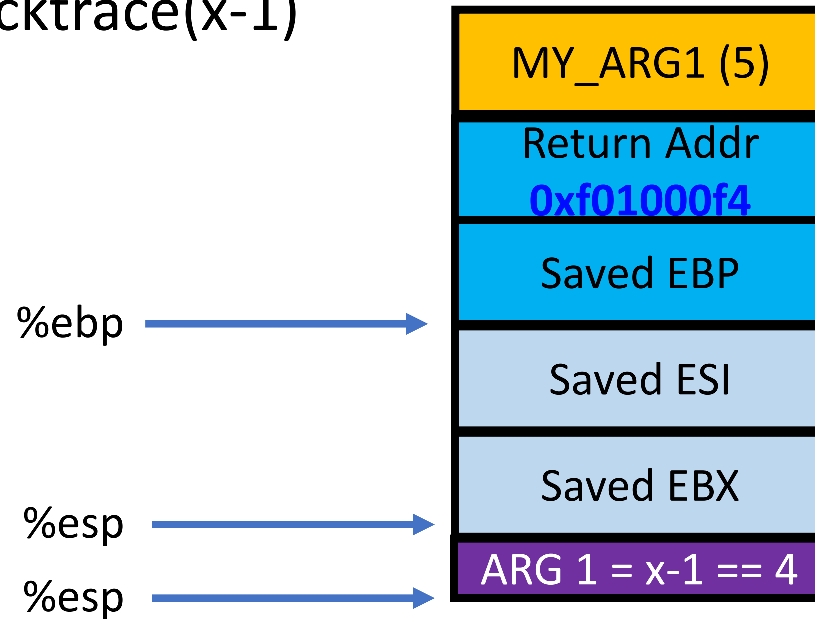


How x86 manages stack?

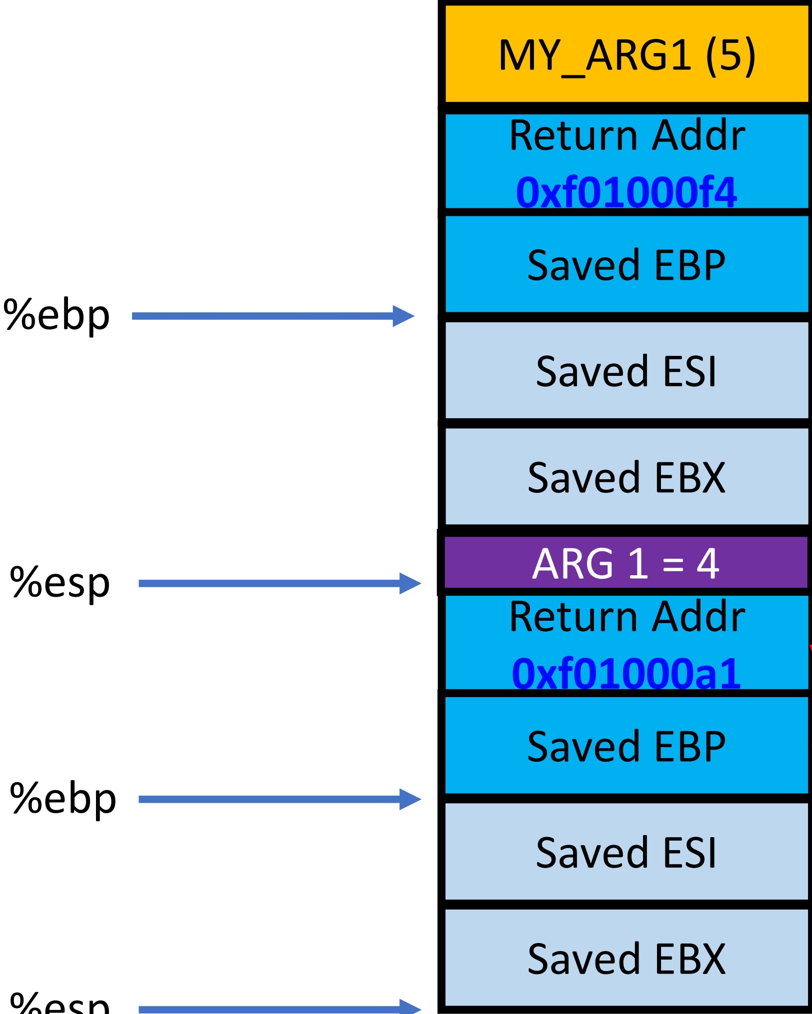
```
0xf0100098 <+88>:    lea    -0x1(%esi),%eax
0xf010009b <+91>:    push   %eax
0xf010009c <+92>:    call   0xf0100040 <test_backtrace>
```

- Call

  test_backtrace(x-1)



How x86 manages stack?

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gdb-peda$ disas test_backtrace
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   0xf0100041 <+1>:     mov    %esp,%ebp
   0xf0100043 <+3>:     push   %esi
   0xf0100044 <+4>:     push   %ebx
```
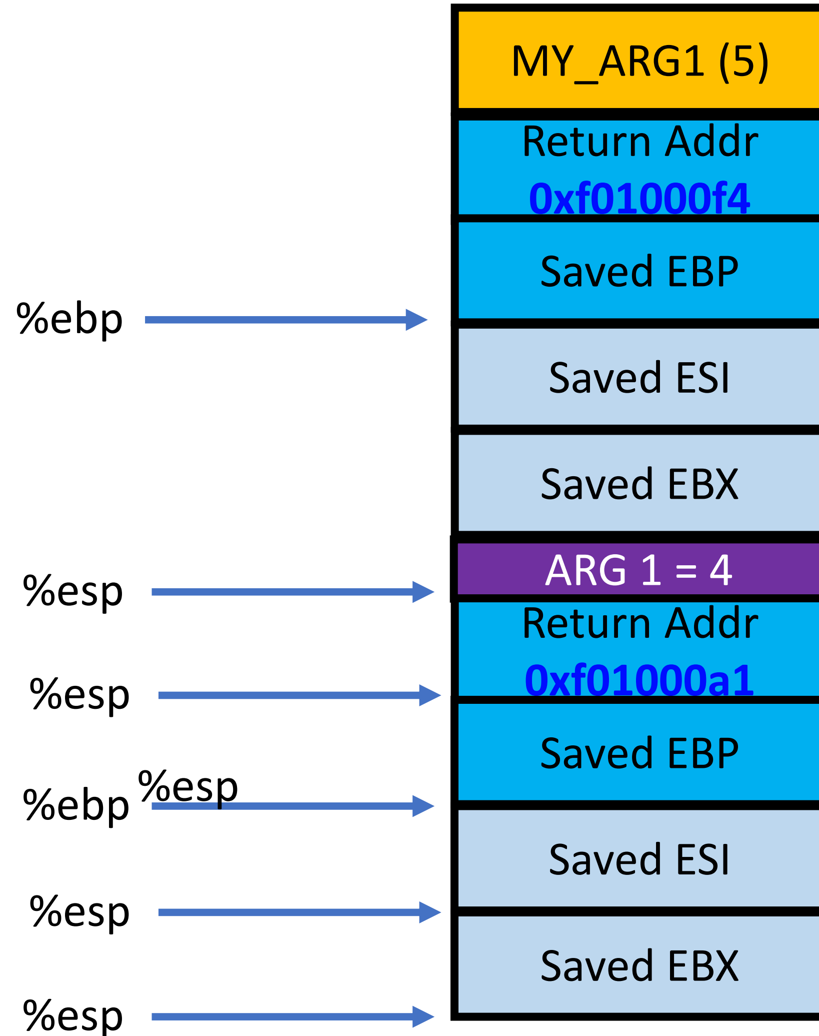

```
0xf0100098 <+88>:    lea    -0x1(%esi),%eax
0xf010009b <+91>:    push   %eax
0xf010009c <+92>:    call   0xf0100040 <test_backtrace>
0xf01000a1 <+97>:    add    $0x10,%esp
```

Do this until the value reaches 0…

```
if (x > 0)
    test_backtrace(x-1);
else
    mon_backtrace(0, 0, 0);
```

How x86 manages stack?




```
0xf0100091 <+81>:    pop    %ebx
0xf0100092 <+82>:    pop    %esi
0xf0100093 <+83>:    pop    %ebp
0xf0100094 <+84>:    ret
```

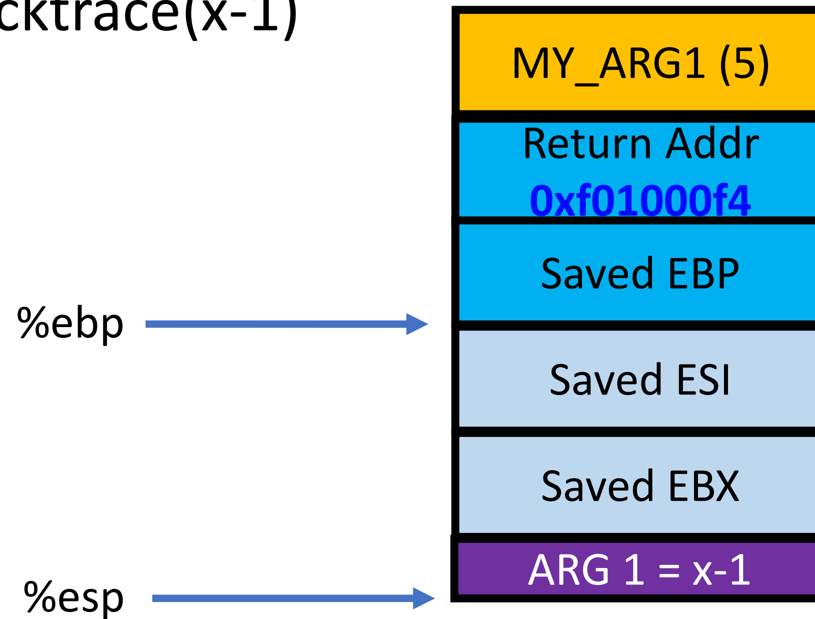
ret == pop %eip

How x86 manages stack?

```
0xf0100098 <+88>:    lea    -0x1(%esi),%eax
0xf010009b <+91>:    push   %eax
0xf010009c <+92>:    call   0xf0100040 <test_backtrace>
```

- Call

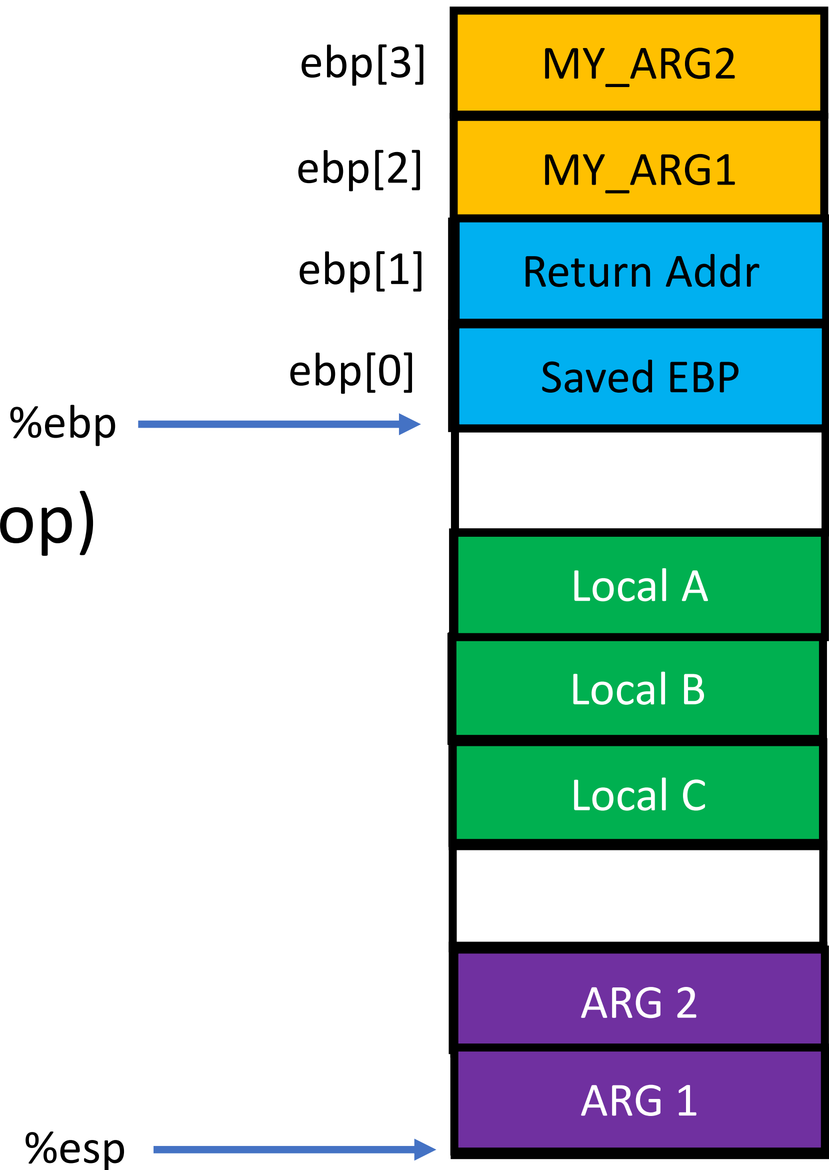
  test_backtrace(x-1)



x86 Stack

- ebp points the boundary of the stack (bottom)
- esp points to the other boundary of the stack (top)

- ebp[0] stores saved ebp
- ebp[1] stores return address
- ebp[2] stores 1st argument
- ebp[3] stores 2nd argument
- …



Hint – Exercise 11

```
Stack backtrace:
  ebp f010ff78  eip f01008ae  args 00000001 f010ff8c 00000000 f0110580 00000000
         kern/monitor.c:143: monitor+106
```

- int *ebp = (int *) read_ebp();
  - cprintf("ebp %08x", ebp)…
- EIP == return address
  - ebp[1] – why?
- Args?
  - Print ebp[2 ~ 6]…